A Glance at Quality of Service Models for Mobile Ad Hoc Networks

Navid Nikaein and Christian Bonnet
Institut Eurécom
2229, route des crêtes
B.P. 193
Sophia Antipolis- France
Firstname.Name@eurecom.fr

Abstract

Mobile ad hoc networking is a challenging task due to the lack of resources reside in the network as well as the frequent changes in network topology. Although lots of research have been done on supporting QoS in the Internet and other networks, they are not suitable for mobile ad hoc networks and still QoS support for such networks remains an open problem. In this paper, we provide a brief overview of current QoS support for Internet and mobile ad hoc networks. We introduce a new definition of QoS in mobile ad hoc network, and base on that a cross-layer QoS model is suggested.

Index Terms

Mobile ad hoc networks, routing, QoS, QoS model, metrics, cross-layer design.

1 Introduction

A mobile ad hoc network *manet* consists of a collection of mobile nodes forming a dynamic autonomous network. Nodes communicate with each other over the wireless medium without the intervention of centralized access points or base stations. Hence, they form a *fully mobile infrastructure*. Each node acts both as a router and as a host. Due to the limited transmission range of wireless network interfaces, multiple *hops* may be needed to exchange data between nodes in the network, which is why the literature sometimes uses the term *multi-hop* network for a *manet*. *manet* was also referred to as a *packet radio network* in the mid-1960 [1, 2]. Such networks are attractive because they can be rapidly deployed anywhere and anytime without the presence of fixed base stations and system administrators.

2 Motivation

Due to the frequent changes in network topology and the lack of the network resources both in the wireless medium and in the mobile nodes, mobile ad hoc networking becomes a challenging task. As a result, routing in such networks experiences link failure more often. Hence, a routing protocol that support QoS for ad hoc networks requires to consider the reasons for link failure to improve its performance. Link failure stems from node mobility and lack of the network resources. Therefore it is essential to capture the aforesaid characteristics to identify the quality of links. Furthermore, the routing protocols must be *adaptive* to cope with the time-varying low-capacity resources. For instance, it is possible that a route that was earlier found to meet certain QoS requirements no longer does so due to the dynamic nature of the topology. In such a case, it is important that the network intelligently adapts the session to its new and changed conditions.

According to RFC 2386 [3], quality of service means providing a set of service requirements to the flows while routing them through the network. We believe that for mobile ad hoc wireless networks, with time-varying low-capacity resources, the notion of being able to meet specific application requirements such as delay is not plausible. Hence, the definition may not be valid for mobile ad hoc networks since even the Internet today, with high-speed high-quality fixed communication links, is unable to deliver guaranteed end-to-end services [4].

3 Pros and Cons of Classical QoS Models for Manet

The presence of mobility implies that links make and break often and in an indeterministic fashion. This dynamic nature makes routing and consequently QoS support in these networks fundamentally different from fixed networks [5, 6, 7, 8]. Further, since the *quality* of the network (in terms of available resources reside in the wireless medium and in the mobile nodes: e.g. buffer and battery state) varies with time, present QoS models for wired networks are insufficient for such networks [9]. It has to be mentioned that a QoS Model does not define specific protocols or implementations. Instead, it defines the methodology and architecture by which certain type of services can be provided in the network. *Integrated services* (IntServ) [10] and *Differentiated services* (DiffServ) [11] are the two basic architectures proposed to deliver QoS guarantees in the Internet. We first introduce these two models as the background:

- ***Integrated Services*—**IntServ architecture allows sources to communicate their QoS requirements to routers and destinations on the data path by means of a signaling protocol such as RSVP [12, 13]. Hence, IntServ provides per-flow end-to-end QoS guarantees. IntServ defines two service classes: *guaranteed service* [14] and *controlled load* [15], in addition to the *best effort* service. The guaranteed service class guarantees to provide a maximum end-to-end delay, and is intended for applications with strict delay requirements. Controlled load, on the other hand, guarantees to provide a level of service equivalent to best effort service in a lightly loaded network, regardless of network load. This service is designed for adaptive real-time applications. As is the case in the Internet, IntServ is not appropriate for mobile ad hoc networks, because the amount of state information increases proportionally with the number of flows, which results in scalability problems.

- ***Differentiated Services*—**DiffServ architecture avoids the problem of scalability by defining a small number of per-hop behaviors (PHBs) at the network edge routers and associating a different DiffServ Code Point (DSCP) in the IP header of packets belonging to each class of PHBs. Core routers use DSCP to differentiate between different QoS classes on per-hop basis. Thus, DiffServ is scalable but it does not guarantee services on end-to-end basis. This is a drawback that hinders DiffServ deployment in the Internet, and remains to be a drawback for *manet* as well, since end-to-end guarantees are also required in *manet*. In DiffServ, we can identify three different classes: *expedited forwarding*, *assured forwarding*, and *best effort*. Expedited forwarding provides a low delay, low loss rate, and an assured bandwidth. Assured forwarding provides guaranteed/expected throughput for applications, and best effort which provides no guarantee.

DiffServ and IntServ require accurate link state (e.g. available bandwidth, packet loss rate , delay, and etc.) and topology information. The time-varying low-capacity resources of the network make maintaining accurate routing information very difficult. However, we think that a quality of service model for *manet* should benefit from the concepts and features of the existing models in order to build on a model that satisfy such networks.

A variant of these two architectures, called a Flexible QoS Model for Manet (FQMM) [16] has been proposed for ad hoc networks. Below, we provide a short summary of FQMM:

- ***Flexible QoS Model for Manet*—**FQMM is a quality of service model for mobile ad hoc networks as its name indicates [16]. FQMM defines three type of nodes: an ingress node which sends date, an interior node which forwards data to other nodes, and an egress node which is a destination. Obviously, each node may have multiple role. This model selectively uses the per-flow state property of IntServ, and the service differentiation of DiffServ. That is to say, for applications with high priority, per-flow QoS guarantees of IntServ are provided. On the other hand, applications with lower priorities are given per-class differentiation of DiffServ. Therefore, FQMM applies a hybrid provisioning where both IntServ and DiffServ scheme are used separately.

In FQMM, both IntServ and DiffServ scheme are separately used for different priority classes. Therefore, the drawbacks related to IntServ and DiffServ remain to be a drawback in FQMM. Moreover, to the best of our knowledge FQMM does not take into account the characteristics of *manet*.

4 Quality of Service in Manet

Unlike fixed networks such as the Internet, quality of service support in mobile ad hoc networks depends not only on the *available resources* in the network but also on the *mobility rate* of such resources. This is because *mobility* may result in link failure which in turn may result in a broken path. Furthermore, mobile ad hoc networks potentially have less resources than fixed networks. Therefore, more criterion are required in order to capture the quality of the links between nodes.

We believe for mobile ad hoc networks, with time-varying low-capacity resources, the notion of being able to guarantee hard QoS is not plausible. Instead, applications must adapt to time-varying low-capacity resources offered by the network. Therefore, the quality of service that an application requires depends on the "quality" of the network. This "quality" should be a function of available resources reside both in the wireless medium and in the mobile nodes in the network as well as the stability of such resources (refer to section 2). Hence, quality of service in mobile ad hoc network could mean *to provide a set of parameters in order to adapt the applications to the "quality" of network while routing them through the network.* Therefore, quality of service routing is a routing mechanism under which paths are generated based on some knowledge of the quality of network, and then selected according to the quality of service requirements of flows. Hence, the task of QoS routing is to optimize the network resource utilization while satisfying application requirements.

4.1 A Cross-Layer Quality of Service Model

We suggest to apply a cross-layer quality of service model that separates metrics at the different layers (i.e. application layer metrics, network layer metrics, and MAC layer metrics) and map them accordingly [17, 18]. This is because the quality of service that an application requires depends strictly on the "quality" of the network. As stated earlier, the quality of network should represent the available network resources reside both in the wireless medium and in the mobile nodes as well as the stability of these resources.

At the application layer, we propose to classify the QoS requirements into a set of QoS priority classes with their corresponding application layer metrics (ALMs). For example, we classify application requirements into three QoS classes, I, II, & III, and map them to appropriate metrics. Class I corresponds to applications that have strong *delay* constraints, such as voice. This class is mapped to the *delay* metric at ALMs. Class II is suitable for applications requiring high *throughput* such as video or transaction-processing applications. Similarly, we map this class to the *throughput* metric at the ALMs. Finally, Class III has no specific constraints, and it is mapped to *best-effort* at the ALMs. This mapping is shown in Fig. 1.

At the network layer, we recommend to use nodes' power state, buffer state, and stability state to characterize the quality of network (see Fig. 1), and we call them network layer metrics (NLMs). The power level represents the amount of available

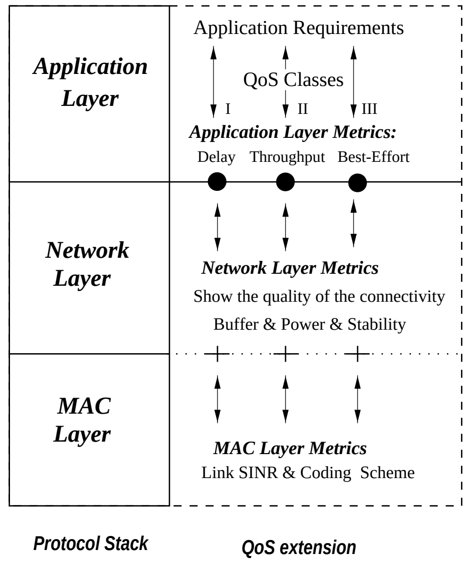

Figure 1: Global view of a cross-layer quality of service model

battery over time (i.e. energy). The buffer state stands for the available unallocated buffer. The stability means the connectivity variance of a node with respect to its neighboring nodes over time. To compute the quality of a path, concave or/and additive functions have to be used in order to represent the NLMs of a path given the value of these metrics for individual nodes on that path. The network layer metrics of a particular node can also reveal whether the node is *forced* to be *selfish* or not. In the selfish mode, a node can cease to be a router and acts only as a host due to its poor quality.

At the MAC layer, the quality of network could mean link signal-to-interference-plus noise power ratio (SINR), and we call it MAC layer metrics (MLM). Link SINR determines the communication performance of the link: the data rate and associated probability of packet error rate or bit rate (bit error rate BER) that can be supported by the link. Links with low SINR are not typically used due to their poor performance, leading to partial connectivity among all nodes in the network. Moreover, it is essential to minimize the volume of traffic being transmitted over the wireless interface because of the scarce wireless resources. This can be achieved via coding schemes. That is why we suggest to apply different coding schemes such as FEC and ARQ for different QoS classes [19]. For example, *forward error correction* (FEC) uses a coding scheme for both error detection and correction which impose constant overhead over the applied data. This scheme is more appropriate for a high priority class, e.g. class I. On the other hand, *automatic repeat request* (ARQ) only uses an error detecting code; where in case of error, a packet is retransmitted. ARQ is feasible as long as the channel bit error rate is not too high and retransmission delay is admissible. The ARQ is more suitable for low priority class, e.g. class III. Hybrid ARQ/FEC techniques take the advantage of the two schemes. If the error in a packet can *not* be corrected by the error correcting code, a retransmission will be demanded. We suggest to apply this technique for the medium priority class, e.g. class II. However, it is important to keep in mind that the bandwidth savings are a trade-off against the processing requirements on the mobile nodes. Hence the complexity of the coding algorithms must also be considered.

Indeed, NLMs and MLM determine the quality of links in order to generate the paths with good quality. They try to evenly distribute the traffic in the network and avoid paths with a low quality regardless of the application. Then, application layer metrics select exactly one path out of the paths with the good quality which is more likely to meet application requirements. This implies that applications may need to adapt to the quality of network. That is why, we propose a cross-layer quality of service model in order to responds to both network and application requirements. This model does not define specific protocols or implementations.

Fig. 1 shows the defined QoS classes together with their ALMs constraints and the corresponding NLMs and MLM. Table 1 shows the mapping between QoS classes, ALMs, NLMs, and MLM. In this model, class I and II can be mapped to the buffer level and hop count at the NLMs and to link SINR at MLM; and class III to stability level and hop count, and to link SINR at MLM. Hence, MAC layer metrics, network layer metrics and application layer metrics might be used as the additional constraints to the conventional ones to determine paths between a source and a destination.

Table 1: QoS Classes & Mapping

Priority Classes	ALMs	NLMs	MLM
Class I	Delay	Buffer & Hop Count	SINR
Class II	Throughput	Buffer & Hop Count	SINR
Class III	Best-Effort	Stability & Hop Count	SINR

As an example to show how an application can adapt to the corresponding ALM and hence to the quality of network, we consider shaping mechanism [9, 20]. Note that, shaping is the process of delaying or dropping packets within a traffic flow to cause them to conform to the QoS state of the selected path [9]. To decide whether to delay or drop the packets, a node checks the application requirements. If the application is delay sensitive–i.e. class I, then the dropping approach may be used. Although this approach implies an increase of loss rate, the probability of the path failure is reduced as it avoids an extra delay. On the other hand, if the application requires low loss rate–i.e. class II, then the delaying approach might more appropriate when the stability is high and hence the path can support an extra delay caused by this approach. At the network layer, routing protocol must be *adaptive* according to given NLMs of nodes in the path generation process between source node and destination node. The MAC layer, on the other hand, can adapt the coding technique to meet the application requirements given current channel and network conditions.

5 Conclusion

In this paper, we provide a brief overview on the quality of service model in Internet and *manet*. We argue that QoS support in manet is fundamentally different from traditional networks because of its particular behaviors. Hence, a new definition of QoS for manet is introduced with the knowledge of such behaviors. We suggest a cross-layer QoS model based on this definition to support adaptivity and optimization across multiple layer of the protocol.

References

[1] Proceeding of IEEE, *Special Issue on Packet Radio Networks*, vol. 75, 1987.

[2] "Packet radio networks," www.tapr.org/tapr/html/pktf.html.

[3] E. Crawley, R. Nair, B. Rajagopalan, and H. Sandick, "A framework for QoS-based routing in the internet," Aug. 1998, RFC 2386.

[4] A. J. Goldsmith and S. B. Wicker, "Design challanges for energy-constrained ad hoc wireless networks," *IEEE Wireless Communications*, 2002.

[5] K. Wu and J. Harms, "QoS support in mobile ad hoc networks," 2001.

[6] S. Chen and K. Nahrstedt, "Distributed quality-of-service routing in ad hoc networks," *IEEE Journal on Selected Areas in Communication*, vol. 17, no. 8, 1999.

[7] D. D. Perkins and H. D. Hughes, "A survey on quality-of-service support for mobile ad hoc networks," *Wireless Communications and Mobile Computing*, 2002.

[8] D. Chalmers and M. Sloman, "A survey of QoS in mobile computing environments," *IEEE Communications Surveys*, 1999.

[9] X. Xiao and L. M. Ni, "Internet QoS: A big picture," *IEEE Network*, pp. 8–18, Match/April 1999.

[10] R. Braden, D. Clark, and S. Shenker, "Integrated services in the Internet architecture: an overview," 1994, IETF RFC 1633.

[11] S. Blake, D. Black, M. Carlson, E. Davies, Z. Wang, and W. Weiss, "An architecture for differentiated services," 1998, IETF RFC 2475.

[12] Lixia Zhang, Stephen Deering, and Deborah Estrin, "RSVP: A new resource reservation protocol," *IEEE network*, 1993.

[13] R. Braden, L. Zhang, S. Berson, S. Herzog, and S. Jamin, "Resource reservation protocol (RSVP) – version 1 functional specification," Sept. 1997, IETF RFC 2205.

[14] S. Shenker, C. Partridge, and R. Guerin, “Specification of guaranteed quality of service,” 1997, RFC 2212.

[15] J. Wroclawski, “Specification of the controlled-load network element service,” 1997, RFC 2211.

[16] H. Xiao, W. K. G. Seahand A. Lo, and K. C. Chua, “A flexible quality of service model for mobile ad-hoc networks,” in *IEEE VTC2000-spring*, Japon/Tokyo, 2000.

[17] Navid Nikaein, Christian Bonnet, Yan Moret, and Idris A. Rai, “2lqos- two-layered quality of service model for reactive routing protocols for mobile ad hoc networks,” in *in Proceeding of SCI - 6th World Multiconference on Systemics, Cybernetics and Informatics*, 2002.

[18] Navid Nikaein and Christian Bonnet, “Layered quality of service model for routing in mobile ad hoc networks,” in *in Proceeding of WMAN*, 2003.

[19] Neda Nikaein, *QoS Control in Wireless IP Access Networks*, Ph.D. thesis, ENST, Sophia-Antipolis - France, October 2000.

[20] C. Aurrecoechea, A. T. Campbell, and L. Hauw, “A survey of qos architectures,” *Multimedia Systems*, 1998.